The Research Challenges of ClassmateAssist: A Personal and Physical Math Coin Tutoring System

Georgios Theocharous
Intel Corporation
Intel Labs
Santa Clara

Nicholas Butko
Cognitive Science Department
University of California
San Diego

Matthai Philipose
Intel Corporation
Intel Labs
Seattle

Abstract

Many elementary mathematics teachers believe that learning improves significantly when students are instructed with physical objects such as coins, called manipulatives. Unfortunately, teaching with manipulatives is a time consuming process that is best with personalized 1-to-1 tutoring. In this paper, we explore the research challenges and solutions of an automated physical and personal tutoring solution.

1 Introduction

The use of physical objects, such as coins, rods, cubes, patterns and other concrete objects called manipulatives, is a widely accepted approach for teaching abstract and symbolic mathematical concepts in kindergarten and early grades [2, 3]. These researchers showed that interaction with concrete objects provides the basis for abstract thoughts. For example, a child might construct an understanding of the meaning of a 5 cent coin by counting a set of 5 pennies and then associating the value of 5 cents with the physical characteristics of a nickel. The child will also be able understand the meaning of the number 5 through the process of grouping the pennies one by one. Unfortunately, teaching early mathematics with coin manipulatives is a time consuming process and ideally occurs as a personal 1-on-1 tutoring with a teacher. Each session may last up to 30 minutes and may have to be repeated many times through the school season before the student finally develops cognitive structures for the different concepts, which include naming the coins, sorting them by size and value, counting them, and adding their values.

In this paper we investigate the challenges in building an automated math coin tutor. Such a tutor is challenging to build, because not only do we ned to deal with tutoring difficulties of teaching mental manipulations of abstract and symbolic structures but also need to deal with the perception of physical objects and social interaction. To develop a solution we require rich data-driven technologies of machine perception and planning under uncertainty. We classified our challenges into 4 areas: Coin Perception, Mood Perception, Teaching Dynamics and Optimal Teaching. Next we summarize our work in each of the research areas. More technical details can also be found in [4].

2 Research Challenges

Coin Perception For our first challenge we implemented a vision-based coin detection, trucking and clustering system, combined with a projection engine . The system was motivated by 70 videotaped sessions of teachers interacting with first grade and kindergarden students as shown in Figure 1.

Mood Perception In our second challenge we are concerned with identifying moods the students go though such as tired, confused and thinking (Figure 2) and then building machine learning models

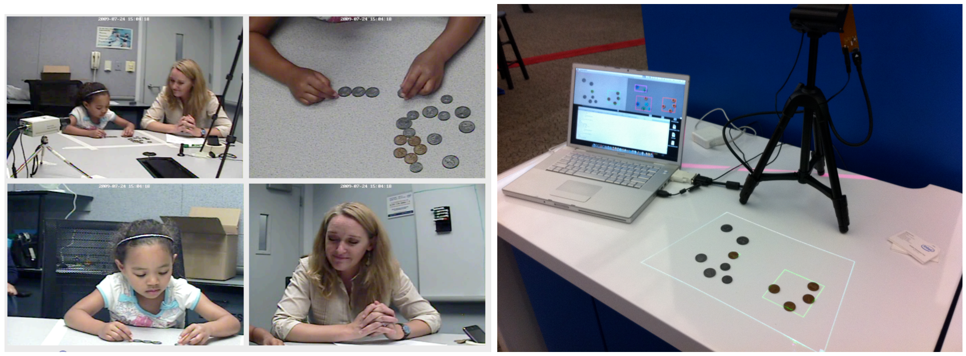

Figure 1: Four video cameras simultaneously captured the interaction from four angles: the whole scene, the table workspace, the student's face, and he teacher's face. The camera/projection system on the right, motivated by the real world coin movements and configurations, recognizes the clusters of coins and types within each cluster. In this instance it projects hints on a table to help the student separate the pennies from the rest of the coins.

for predicting them. Identifying positive learning moods and implementing strategies that encourage them is an important element of effective tutoring. To encode the various student moods we used facial expression recognition algorithms [1].

Figure 2:

Teaching Dynamics For the third challenge we had to identify the type of lessons and hints that the teachers give, what mathematical concepts each lesson provides, and how do the teachers decide when to give a lesson and a hint.

Optimal Teaching Finally, all the elements of the systems need to be encoded in some formal computational decision making approach, which would be able to reason about and diagnose true student moods and concept level and give appropriate lessons and hints to encourage positive mood learning as well as advance the concept level. For this, we chose the framework of Partially Observable Markov Decision Processes (POMDPs), where we we define *Observations* to be coin configurations and and facial expression, *States* to the real underlying moods and concepts and *Actions* to be the particular lessons and hints.

References

[1] Gwen Littlewort, Marian Stewart Bartlett, Ian Fasel, Joshua Susskind, and Javier Movellan. Dynamics of facial expression extracted automatically from video. In *J. Image And Vision Computing*, pages 615–625, 2004.

[2] Jean Piaget and Alma Szeminska. *The Childs Conception of Number*. W. W. Norton Co., New York, 1941.

[3] Evelyn J. Sowell. Effects of manipulative materials in mathematics instruction. *Journal for Research in Mathematics Education*, 20(5):498–505, November 1989.

[4] Georgios Theocharous, Nicholas Butko, and Matthai Philipose. Designing a mathematical manipulatives tutoring system using POMDPs. In *POMDP Practitioners Workshop: solving real-world POMDP problems, ICAPS*, 2010.